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NASA GLOBAL ATMOSPHERIC SAMPLING PROGRAM (GASP) DATA REPORT FOR TAPE VL0005

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16. Abstract

Fully automated GASP air sampling systems on board several commercial B-747 aircraft in routine airline service are obtaining measurements of trace constituents in the upper troposphere and lower stratosphere. Atmospheric ozone, water vapor, and related flight and meteorological data were obtained during 214 flights of a United Airlines B-747 and two Pan American World Airways B-747's from March through June 1976. In addition, trichlorofluoromethane data obtained from laboratory analysis cf two whole air samples collected in flight are reported. These data are now available on GASP tape VL0005 from the National Climatic Center, Asheville, North Carolina. In addition to the GASP data, tropopause pressure fields obtained from NMC archives for the dates of the GASP flights are included on the data tape. Flight routes and dates, instrumentation, data processing procedures, and data tape specifications are described in this report. Selected analyses including ozone and sample bottle data are also presented.

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SUMMARY

Atmospheric trace constituents in the upper troposphere and lower stratosphere are being measured as part of the NASA Global Atmospheric Sampling Program (GASP), using fully automated air sampling systems on board several commercial B-747 aircraft in routine airline service. Measurements of atmospheric ozone and water vapor, and related meteorological and flight information were obtained during 214 GASP flights from March 25 through June 13, 1976. Also, the results obtained from trichlorofluoromethane analysis of two whole air bottle samples are reported. These data are now available from the National Climatic Center, Asheville, North Carolina. In addition to the data from the aircraft, tropopause pressure data obtained from the National Meteorological Center (NMC) archives for the dates of the flights are included. This report is the fifth of a series of reports which describes the data currently available from GASP, including flight routes and dates, instrumentation, data processing procedure, data tape specifications, and selected analyses.

INTRODUCTION

This report announces the availability of atmospheric trace constituent data obtained at altitudes from 6 to 14 km during several flights of a United Airlines B-747 (N4711U) and two Pan American World Airways B-747's (N655PA and N533PA) from March - June 1976.

The objectives of the NASA Global Atmospheric Sampling Program are to provide baseline data of selected atmospheric constituents in the upper troposphere and lower stratosphere for the next 5-to-10 year period, and to document and analyze these data to assess potential adverse effects between aircraft exhaust emissions and the natural atmosphere. At present there is much uncertainty in environmental impact studies on this subject due to the lack of comprehensive, long-term upper atmospheric data (refs. 1 and 2).

The GASP program began in 1972 with a feasibility study of the concept of using commercial airliners in routine

service to obtain atmospheric data. This program has progressed from design and acquisition of hardware (ref. 3) to collecting global data on a daily basis. Fully automated GASP systems are now operating on a United Airlines B-747, two Pan American World Airways B-747's, and a Qantas Airways of Australia B-747. The United airliner is collecting data over the contiguous United States and between the west coast and Hawaii. Global coverage is provided by the Pan American and Qantas B-747's. Pan Am routes from the United States include around-the-world flights in the Northern Hemisphere, transatlantic flights to Europe, transpacific flights to the Orient, intercontinental flights to Central and South America, and occasionally transpacific flights to Australia. More frequent coverage in the Southern Hemisphere is provided by the Qantas B-747 on transcontinental Australian flights and on flights from Australia to the South Pacific and Australia to Europe. The GASP system design, the measurement instruments, the on-board computer for automatic control and data management, and system maintenance procedures are described in reference 4.

This report is the fifth in a series of reports to announce the availability of GASP data from the National Climatic Center, Asheville, North Carolina, 28801. Northern hemisphere data for March 11 - March 30, 1975 have been previously reported and analyzed (tape VL0001; refs. 5, 6 and 7). Data over the contiguous United States and to Hawaii for March - October, 1975 are provided on GASP tape VL0002 (ref. 8). Data obtained in May 1975 on flights in North, Central, and South America, and from the United States to the Orient are provided on GASP tape VL0003 (ref. 9). Global data for December 26, 1975 through March 25, 1976 are available on GASP tape VL0004, with documentation provided by reference 10. Data for March 25 through June 13, 1976 are now available on GASP tape VL0005. In addition to the atmospheric constituent measurements, the data on this tape include related meteorological and flight information from the aircraft systems, and tropopause pressure fields obtained from the National Meteorological Center (NMC) for the dates of the GASP flights.

ROUTE STRUCTURE AND DATA ACQUISITION

Flight routes for which data are given on GASP tape VL0005 are shown on figure 1. All flights occurred between March 25 and June 13, 1976. On the tape, GASP data are grouped and identified by flights with the airports of departure and arrival designated by the standard three-letter airport codes (ref. 11). A listing of flights included in tape VL0005 by airport-pair, date, and data acquisition time, is given in table I.

For each flight, data acquisition begins on ascent through the 6 km altitude flight level, and terminates on descent through 6 km. A complete GASP sampling cycle is 60 minutes, divided into 12 five minute segments. A 16 second recording is made at the end of each sampling segment. During alternate segments (at 10 minute intervals), air sample data are recorded for all instruments. During the intervening segments the system is in one of six different calibration modes to allow for in-flight checks on instrument operation (if required). Whenever any calibration mode is not needed for a given instrument, that instrument acquires air sample data during the segment.

Cassette tapes, recorded in serial format, are removed from the aircraft at approximately two week intervals and transcribed to computer-compatible form for data reduction. At this stage, laboratory instrument calibration information required for data processing is included, redundant and non-usable data are removed, and the data are re-transcribed to final form and units. The detailed specifications and formats for the GASP data are given in appendix A. Data for each flight begins with an FLHT record (table A-I) to provide flight identification information. This record is followed by a series of DATA records (table A-II), one for each recording made during the flight.

MEASUREMENTS

Ozone

Ozone measurements are made using a continuous ultraviolet absorption ozone photometer (ref. 12). The concentration of atmospheric ozone is determined by measuring the difference in intensity of an ultraviolet light beam which alternately passes through the sample gas and an ozone-free zero gas (generated within the instrument). The range of this instrument is from 3 to 20,000 ppbv (parts per billion by volume), with a sensitivity of 3 ppbv. Data from flight tests of the instrument are given in reference 13. The ozone instrument is checked at NASA-Lewis (over the range 0 to 1000 ppbv) against an ozone generator which is calibrated by the one percent neutral buffered potassium iodide (KI) method (ref. 14). The estimated accuracy of the KI procedure is seven percent.

In-flight monitoring of the ozone instrument includes measurement of the instrument zero by flowing the sample through a charcoal filter external to the instrument, and measurement of the electronic span setting and control frequencies available from the instrument. For all GASP ozone instruments, the span is set by the manufacturer at

58200 counts. The instrument is not calibrated in-flight with an ozone calibration gas due to the difficulty of generating a precisely known ozone concentration in the flight system. Periodic checks for calibration consistency are performed in the laboratory.

The destruction of ozone in the Teflon sample lines from the inlet probe to the instrument, and in the Teflon-coated diaphragm pump that raises the sample pressure to 100 kPa (1 atm), has been measured under conditions simulating operation in flight. The ozone mixing ratio at the probe inlet (O3, in ppbv) is expressed in terms of the measured ozone mixing ratio (O3m, in ppbv) as

$$O3 = a(O3m)^{b} + \frac{O3m}{1 + c(O3m)} + d \qquad (1)$$

with the constants a, b, c and d determined by a regression analysis on the appropriate destruction test data. For all flights on tape VL0005, the ambient ozone mixing ratios were determined using equation (1) with $a = 0.19$, $b = 1.0$ and $c = d = 0$. The linear relationship between O3 and O3m thus defined, and the data from which it was determined are shown in figure 2. The uncertainty in this approximation is $\pm$ 8 percent. The destruction constants used are given in the FLHT record for each flight (see table A-I).

The form chosen for equation (1) is based on the ozone destruction mechanisms expected in the GASP system. If $b = 0.5$ in the first term, this term then approximates destruction of ozone in the sample lines (c.f. ref. 15). If $c > 0$ in the second term, this term is of the type which describes thermal decomposition of ozone (refs. 16 and 17). This mechanism could be important in the pump as the sample is heated by the (approximately) 3:1 compression. The percentage of the incoming ozone destroyed by the line mechanism decreases with increasing concentrations, whereas the percentage of the incoming ozone destroyed by the thermal mechanism increases with increasing concentration. Since both mechanisms are likely contributing to the system destruction, it is not surprising that the destruction data are approximated well with a linear relationship which gives a constant percentage destruction.

Water Vapor

Atmospheric water vapor is measured with an aluminum oxide dew-frost point hygrometer (ref. 18). The sensing element consists of a small strip of aluminum which is anodized to provide a porous oxide layer. A very thin coating of gold is evaporated over this structure. The

aluminum base and the gold layer form the two electrodes of a capacitor whose impedance varies with the amount of water adsorbed on the porous surface.

This instrument provides dew-frost point temperatures (DFPT) from -110 degrees C to +40 degrees C for air sample temperatures from -65 degrees C to +40 degrees C. The air temperature is measured with a thermistor mounted on the sensor probe. The sensors are calibrated by the manufacturer, with a specified DFPT accuracy of ± 2 degrees C for -60 degrees C < DFPT ≤ +40 degrees C and ± 3 degrees C for -110 degrees C ≤ DFPT ≤ -60 degrees C.

The sensors are re-calibrated in an environmental chamber at NASA-Lewis prior to installation on the aircraft. Calibration gas is provided by blending room air (DFPT = 10 degrees C), laboratory service air (DFPT = -40 degrees C), and liquid nitrogen boil-off (DFPT = -70 degrees C). The calibration is performed by comparing the aluminum oxide sensor output with the dew-frost point temperature measured by a cooled-mirror hygrometer. Because the sensor output varies with air-sample temperature, calibration is performed at room temperature, -20 degrees C and -40 degrees C. Upon removal from the aircraft, sensors are re-calibrated again at room temperature. Data are used only if the recalibrations are within the limits specified above.

The water vapor sensor is mounted in a de-iced airscoop of the type used on B-747 aircraft for measurement of outside air temperature. The water vapor sensor and the air temperature thermistor are mounted within the scoop as shown in figure 3. This mounting is similar to that of the "B-57 Air Sampler" described in reference 19. Because the scoop mount results in measurement at stagnation conditions, the water vapor-pressure calculated from the indicated DFPT is corrected by the ratio of static to total pressure, and then used to calculate the ambient water-vapor mixing ratio (in parts per million by weight, ppmw) and the ambient air dew-frost point.

Laboratory tests on the aluminum oxide hygrometer have shown several serious deficiencies which must be considered in evaluating the flight data. In these tests the response of the aluminum oxide hygrometer was compared to two cooled-mirror hygrometers; an aircraft-type undergoing response testing with the aluminum oxide hygrometer, and the laboratory standard cooled-mirror hygrometer mentioned previously. The DFPT readings of the two cooled-mirror hygrometers generally agreed to within 1 degree C. Their response was faster than the response of the aluminum oxide hygrometer by about a factor of 10, thus the cooled-mirror hygrometer data were used as actual dew-frost point temperature.

__Response to step change in DFPT at constant sensor temperature__. The time constant (to achieve 63 percent of a step change) of the aluminum oxide hygrometer was found to vary from 8 to 30 minutes depending on the gas (sensor) temperature and the magnitude and direction of the step change. In going from wet-to-dry conditions, the indicated DFPT was higher than the actual DFPT, and conversely, in going from dry-to-wet the indicated DFPT was lower than the actual DFPT.

__Response to step change in sensor temperature at constant DFPT__. As mentioned in a previous paragraph, the indicated DFPT is dependent on the equilibrium sensor temperature. This effect is included in the data reduction through the use of temperature dependent calibration curves. In addition, however, the sensor has been found to have a transient response to changes in ambient temperature at constant DFPT. This response appears to be dependent on both the magnitude of the temperature change, and the rate of change. In response to a decrease in temperature of 20 degrees C at the rate of 2 degrees C/min, the indicated DFPT decreased during the temperature transient to less than the actual DFPT, and then slowly increased toward the true value with a time constant of approximately an hour. Thus a decreasing ambient temperature at constant dew-frost point will result in indicated DFPT values which are too low, and conversely increasing ambient temperature at constant dew-frost point will result in indicated DFPT values which are too high.

__Sensor response during simulated climbout__. The most severe gradients in ambient temperature and water vapor are encountered as the aircraft climbs to cruise altitude, with ambient temperature and DFPT both decreasing. The response characteristics described in the preceding paragraphs suggest that the aluminum oxide hygrometer would indicate too high a DFPT in response to the decreasing humidity, but would indicate too low a DFPT in response to the decreasing temperature. Thus the possibility exists for compensating effects.

__Response following saturation__. The recovery of the sensor from saturated conditions, as would be encountered with the passage of the aircraft through clouds, was found to be very slow. The only available test data showed that, after having been subjected to saturated conditions for 40 minutes, the aluminum oxide hygrometer continued to indicate saturation for an additional 30 minutes after the air was no longer saturated. The test was terminated at this time, and no data are available for the time required for the aluminum oxide hygrometer reading to return to the true DFPT. This slow response characteristic is apparent in the flight data also whenever prolonged saturation is indicated.

In spite of its stated limitations, it is felt that the water vapor measurements obtained with the aluminum oxide hygrometer may be of interest, and thus these data are reported, when available, as both dew-frost point temperature (DFPTA) and water vapor mixing ratio (WVMRA) in the DATA records (see Table A-II). Whenever the indicated dew-frost point temperature is equal to the static air temperature, DFTAGA = "S", as a flag to the fact that saturated conditions have been encountered.

Cloud Detector

Flight test experience with the light-scattering particle counters included in the GASP systems has indicated that flight through clouds results in a significantly greater count of the largest size particles (D > 3 micrometers) than is obtained in clear air. A simple cloud detector is thus available by observing the counting rate of the largest size particles. This signal is monitored for 256 seconds prior to each data recording. The time (in seconds) during which the cloud rate, CLDRT, is greater than a preset level, CLDHI, is interpreted as time in clouds (CLSEC; see table A-II). The CLDHI level was programmed on board the United airliner based on visual observation of a light haze, and corresponds to a local particle density (for D > 3 micrometers) of 66,000 particles/cubic meter. If CLSEC > 0, CLTAG = "C". If cloud data are not available, CLTAG = "M".

The number of cloud encounters (CLAYR, see table A-II) is also available. Whenever clouds are detected (CLDRT > CLDHI), this is interpreted as a continuous encounter until cloud free air is detected. This determination requires a second preset level, CLDLO. If n is the number of times that the cloud rate crosses CLDHI and CLDLO (or CLDLO and CLDHI) in succession, then CLAYR = (n+1)/2. For the data on tape VL0005, CLDLO was set at CLDHI/8.

The cloud data are particularly useful as a supplement to the water vapor data. If there is a continuous or frequent indication of clouds, the dew frost point temperature (DFPT) should remain at, or near, the static air temperature (SAT). However, if the DFPT remains equal to SAT in the absence of any cloud indication, the water vapor data should be considered suspect based on the slow response characteristics of the aluminum oxide hygrometer as discussed previously.

Flight Data

In addition to the air sample measurements, aircraft flight data are obtained with each data recording to

precisely describe conditions when the data are acquired. Aircraft position, heading, and the computed wind speed and direction are obtained from the inertial navigation system. Altitude, air speed, and static air temperature are collected from the central air data computer in the aircraft. Vertical acceleration information (an indication of turbulence) is taken from the aircraft flight recording system. Date and time are provided by a separate GASP clock-calendar unit. The formats and units for these data are given in table A-II.

Bottle Samples

Atmospheric concentration data for trichlorofluoromethane (F-11) were obtained by exposure and subsequent laboratory analysis of whole air "grab" samples. Bottle exposures are programmed to occur at altitudes greater than 9.3 kilometers on every third calendar day, provided that an unexposed bottle is available. Bottle data are included in the FLHT record (table A-I) for each flight. If an exposure occurs (SBUEX = "T"), and data from the laboratory analysis are available (SDATA = "T"), constituent data are reported in units of parts per trillion by volume (pptv). The date, time, altitude, and position for the beginning and end of the exposure are also reported. During a bottle exposure, the GASP system is in a continuous record mode (MODE = 10, see table A-I) to provide a record of the atmospheric conditions which the aircraft encountered during the exposure period.

Sampling system. The sample is taken from a 1.90 cm dia. stainless steel line, which is connected to the inlet probe through an expanded duct section. The sample line is continuously purged, with the aid of a bypass line installed just upstream of the sample bottle unit, to clear the duct wall surfaces of possible contamination by adsorbed chlorofluoromethanes.

Each sample bottle unit consists of four one-liter stainless-steel cylindrical sample bottles. These bottles are electropolished, cleaned, baked, and purged, then filled with pure inert gas to avoid contamination. Hand operated bellows valves are attached at each end of the bottle to form an integral sub-assembly and to facilitate handling and processing procedures. Each sample bottle sub-assembly is connected in series to individual inlet and exit solenoid valves which operate on remote command from the GASP system control unit.

Bottle exposures are normally five minutes in duration. During this time, both the inlet and exit solenoid valves are open. The sampling time was selected to provide at

least ten total volume changes to purge the bottle and sample lines prior to entrapment of the sample. The sample flowrate through the bottle is limited to eight actual liters/minute by an orifice installed in the line downstream of the exit valve.

<u>Sample bottle preparation</u>. The bottle sub-assemblies are baked at approximately 300 degrees C for 40 hours or more, during which they are continuously purged with pure helium or nitrogen at a flow rate of 100 standard cc/minute. The final fill pressure is about 172 kPa. At least one bottle from each baked group is pumped down to sub-atmospheric pressure and stored for about a day to allow for wall desorption, and analyzed for halocarbons. Upon zero level verification, the bottle sub-assemblies are installed in sample bottle units. Each unit is then leak checked with the inlet and exit sample lines evacuated using a helium mass spectrometer leak detector.

<u>Trichlorofluoromethane (F-11) analysis</u>. Bottle samples were analyzed at Lewis utilizing a gas chromatograph with an electron capture detector. For determining F-11 concentrations, the chromatograph was equipped with a Porasil C column (100-150 mesh, 3.2 mm dia. x 4.0 m long) maintained at a temperature of 60 degrees C. A sample loop volume of 20 cc at nominally 13 kPa was flushed into the chromatographic column by helium carrier gas flow at about 38 cc/min. The chromatographic retention time was nominally nine minutes. The electron capture detector element was a tritium impregnated scandium foil type maintained at a temperature of 240 degrees C. Instrument sensitivity was determined to be less than 10 pptv.

Calibration was obtained by inter-laboratory comparisons of standards supplied by NOAA Environmental Research Laboratories (Boulder, Colorado) and Washington State University. These standards were derived from the "Halocarbon Analysis and Measurement Techniques Workshop" held at Boulder on March 25-26, 1976. A peak height comparison with these known calibration gases was used to obtain the data included on tape VL0005. Duplicate determinations were made for each sample and the results were averaged. Measurement precision was estimated to be about ± 5 percent.

<u>Sample pressure considerations</u>. Each whole air sample from which data are reported here was obtained at a pressure slightly above the ambient pressure at the exposure altitude. Concern about adsorption-desorption of halocarbon from the walls of the sample containers at low sample pressures has been expressed by participants at the Boulder Workshop, and wall effects have been observed in recent work at the NOAA Environmental Research Laboratories (ref. 20).

Tests at Lewis have shown that when unstable wall conditions exist, they are revealed by the initial zero halocarbon check after storage at low pressure (see Sample bottle preparation). Our tentative conclusion is that the effects are minimal for the data reported.

Tropopause Pressure Data

The National Meteorological Center (NMC) is presently maintaining a library of gridded meteorological data fields accessible on various disk and magnetic tape systems (ref. 21). Briefly, the data are interpolated to points on the NMC 65 X 65 grid, a square matrix map transformed from a polar stereographic map of the Northern Hemisphere. Among these gridded data are tropopause pressures, available on a twice daily basis (0000 and 1200 GMT).

The NMC tropopause pressure data arrays are included, when available, for the dates of the GASP flights to provide independent data for analysis of the constituent behavior. The NMC reporting periods for which these data appear on tape VL0005 are given in table II. The tropopause pressure arrays form a separate file (see appendix A) following the GASP data. Each array (4225 points) is written as seven TRPR records (table A-III). Coordinates for these data are the NMC 65 X 65 matrix. The relations for obtaining latitude and longitude from the NMC coordinates are given in appendix B. The aircraft location for each GASP DATA record is given both in NMC coordinates and latitude and longitude (see table A-II).

The tropopause pressure corresponding to each GASP data location is obtained by time and space interpolation from the NMC arrays. These pressures and the corresponding geopotential heights for the standard atmosphere are included in the GASP DATA records (TRPRMB and TRPRHM in table A-II). For normal interpolations (within a 12 hour interval) TPTAG = " ". If however, NMC data are missing for one reporting period such that the interpolation must be performed within a 24 hour interval, TPTAG is set = "L". If NMC data are missing for two or more consecutive reporting periods the time interpolation is not performed. In this case if the time of the GASP data point is within six hours of an NMC reporting period for which data are available, the space interpolated values at that reporting period are returned and TPTAG is set = "E", but if the time of the GASP data point is not within 6 hours of an NMC reporting period for which data are available, TRPRMB and TRPRHM are set = 0, and TPTAG is set = "M". Whenever tropopause pressure values are available, DELP = TRPRMB - PAMB, and DELHGT = ALTMAV - TRPRHM are also reported.

From September 1974, through mid-December 1975, the location of the tropopause surface archived by NMC was determined by means of the Flattery global analysis method (ref. 22). This procedure made use of the vertical temperature profiles calculated for each NMC grid point, and tested the slope of the profile curve upwards from the first mandatory pressure level. However, as of December 17, 1975, (1200 GMT), the determination of the tropopause pressure surface has been formulated using a different analysis scheme. This change adopts a procedure conceived by Gustafson (ref. 23) which attempts to model the tropopause in terms of the potential temperature, which is a meteorologically significant height indicator. The method is based on climatological observations that the tropopause surface is generally in phase with pressure variations along potential temperature surfaces in the lower stratosphere. The modeled tropopause is constrained to lie near various, pre-selected, potential temperature surfaces, depending on month and geographical location.

The Gustafson method first calculates a potential temperature, THETA, profile above each of the 4225 NMC grid points from the ambient temperature, T, at each of the reported pressure levels, p, from the following definition of the potential temperature:

$$\mathrm{THETA} = (T)(1000/p)^{.2857} \qquad (2)$$

This profile is then scanned downward, and delta THETA/delta p is evaluated for each layer, until a distinct stability transition occurs near the expected THETA location of the mean tropopause. The temperature at the top of this layer is defined as the tropopause temperature. Next, temperatures are calculated upwards from the bottom of the layer assuming pre-selected tropospheric lapse rates (depending on temperature range). The pressure at which this profile attains a temperature equal to the previously determined tropopause temperature is defined as the tropopause pressure. Many details have been omitted from this brief description, and the reader would be best advised to refer to reference 23.

The differences between the tropopause pressures identified by the Gustafson and Flattery methods are significant. These differences are apparent in the monthly zonal averages at 5 degree latitude intervals shown in table III. Here, the values for January through November 1975 were obtained with the Flattery analysis, and values for January through October 1976 were obtained with the Gustafson method. Since the NMC changeover occurred in mid-December 1975, values for that month are a composite. From the table, it is apparent that not only does the

current (Gustafson) analysis render tropopause pressures greater than those derived from the previous (Flattery) method, but that the differences increase toward the equator. We believe that the tropopause locations south of 30 degrees N, as reported after December 17, 1975, are suspect, and should be used with caution in analyzing GASP data. North of 30 degrees, the new tropopause pressures seem to fall within the statistical range of observed, mean pressures reported by Reiter (ref. 24) for the North American continent.

SELECTED ANALYSES

Previous reports in this series have included case studies of selected GASP flights to show the interrelationships between constituent measurements and their relation to meteorological and flight parameters (refs. 5, 8-10). Since GASP in-situ ozone measurements began in March 1975, we are now in our second year of reporting data for this species.

Zonal averaged Northern Hemisphere ozone data for March and May of 1975 and 1976 at flight altitudes from 10.5 to 11.5 km are shown in figure 4. Each curve represents from 600-900 individual measurements which are a mix of global data from N655PA and N533PA and domestic U.S. data from N4711U. The GASP ozone data sets for 1975 and 1976 have been merged to provide the zonal mean levels for March and May shown in figure 5. Also shown on this figure are the North American mean levels at 11 km computed from data in references 25 (1963-1964) and 26 (1963-1971). For March (fig. 5a), a local minimum in the mean ozone curves is evident at mid-latitudes in both the GASP data and the 1963-1964 data (ref. 25). This does not appear in the reference 26 data, most likely because variations in the mean location of the jet stream have caused this to be averaged out over the longer time interval.

As noted previously in this report, the method used by NMC to calculate tropopause pressures was changed on December 17, 1975, and the tropopause pressures archived since that date appear to differ significantly from previous levels (see table III). In view of this change, and if it is assumed that no gross changes in atmospheric ozone levels occurred during the 1975-1976 period (cf. fig. 4), it is not surprising that the vertical ozone profiles as a function of pressure intervals from the NMC tropopause are significantly different for our 1975 and 1976 data (fig. 6). In this figure the 1975 curve represents 4243 observations from March 11 through October 21, 1975, and the 1976 curve represents 9,071 observations from December 26, 1975 through June 13, 1976. Also shown in figure 6 is the

mid-latitude vertical ozone profile for the 1976 U.S. Standard Atmosphere (ref. 27). Here the pressure-altitude relation of the standard atmosphere was used, and the tropopause was assumed to be at 226.32 hPa (11 km).

The 1975 GASP ozone profile agrees more favorably with the standard atmosphere profile than does the 1976 GASP profile. This is consistent with our previously successful use of the 1975 (Flattery) tropopause pressure data in analyzing GASP data (refs. 5-9, and 28), and the apparent tendency of the 1976 (Gustafson) tropopause pressure data to underestimate the height of the tropopause (ref. 10). Although our investigation of the different tropopause pressure schemes and their usefulness in analyzing GASP data is presently incomplete, the results to date have been included here to alert GASP users to the fact that the differences in the NMC archived tropopause pressure data for 1975 and 1976 can have a significant impact on data analysis. If not recognized, these tropopause pressure differences could lead to conflicting conclusions about the variation of atmospheric constituents across the tropopause.

Data from five sample bottle exposures have been included in GASP data records for the period March - June 1976. Three of these were on tape VL0004 (ref. 10), and two are on tape VL0005. Because of the limited number of samples, these data and the related exposure information are given in table IV. Whenever the location of the exposure altitude with respect to the local tropopause was evident, either from the GASP ozone and temperature data and/or the NMC tropopause pressure data, this information has been entered in the table. The sample pressures shown in table IV are slightly less than total pressure for each exposure. Although the GASP trichlorofluoromethane data are too limited to support any conclusions about variability of this species, it can be observed that the F-11 measurements are within the range of measurements reported in reference 29.

CONCLUDING REMARKS

Atmospheric constituent data and related flight and meteorological data obtained during 214 flights of GASP-equipped United Airlines and Pan American World Airways B-747's from March 25 - June 13, 1976 are now available. Tropopause pressure fields obtained from NMC data archives for the dates of the GASP flights are included as a supplement to the GASP data. These data may be obtained as GASP tape VL0005 from the National Climatic Center, Federal Building, Asheville, NC, 28801. Flight routes and dates, instrumentation, data processing procedures, tape specifications and formats, and selected analyses are discussed in this report.

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Ozone measurement	- M. W. Tiefermann
Water Vapor measurement	- T. J. Dudzinski
Cloud detector and particle measurement	- T. W. Nyland
Sample bottle preparation and analysis	- G. M. Boyd
Data acquisition system	- T. W. Nyland
Data tape specifications and formats	- F. P. Michaelis

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TABLE I - GASP FLIGHTS ON TAPE VL005

A) FILE 0001 (UAL-N4711U)

	FLIGHT ROUTE	DEPARTURE DATE	DATA TIME INTERVAL (GMT)	DATA
1	SFO-HNL	3/29/76	2232-0247	O W
2	HNL-ORD	3/30/76	0637-1333	O W
3	ORD-LAS	3/30/76	1707-1944	O W
4	LAS-ORD	3/30/76	2210-0107	O W
5	ORD-CLE	3/31/76	0323-0338	O W
6	CLE-ORD	3/31/76	1423-1443	O W
7	ORD-HNL	3/31/76	1732-0057	O W
8	HNL-ORD	4/ 1/76	0445-1157	O
9	ORD-YYZ	4/ 1/76	1410-1435	O
10	YYZ-ORD	4/ 1/76	1652-1722	O
11	ORD-SFO	4/ 1/76	2005-2358	O
12	SFO-HNL	4/ 2/76	2248-0305	O W
13	HNL-LAX	4/ 3/76	1928-2310	O W
14	CLE-ORD	4/ 7/76	1423-1443	O
15	ORD-HNL	4/ 7/76	1717-0108	O
16	HNL-LAX	4/ 8/76	1941-2331	O W
17	LAX-DEN	4/ 9/76	0145-0248	O W
18	DEN-LAX	4/ 9/76	1813-1938	O W
19	LAX-HNL	4/ 9/76	2153-0224	O W
20	HNL-ORD	4/10/76	0442-1132	O W
21	ORD-YYZ	4/10/76	1358-1428	O W
22	YYZ-ORD	4/10/76	1648-1718	O W
23	ORD-HNL	4/10/76	2008-0353	O W
24	SFO-HNL	4/11/76	2350-0355	O W
25	HNL-ORD	4/12/76	0949-1339	O W
26	ORD-LAS	4/12/76	1710-1956	O W
27	ORD-CLE	4/13/76	0240-0300	O W
28	CLE-ORD	4/13/76	1416-1441	O W
29	ORD-HNL	4/13/76	1727-0056	O W
30	HNL-ORD	4/14/76	0434-1142	O W
31	ORD-SFO	4/14/76	2317-0231	O W
32	SFO-ORD	4/15/76	1849-2141	O W
33	SFO-HNL	4/17/76	0421-0828	O W
34	HNL-LAX	4/17/76	1937-2343	O
35	LAX-DEN	4/18/76	0141-0303	O
36	LAX-HNL	4/18/76	2134-0202	O
37	HNL-ORD	4/19/76	0433-1144	O W
38	HNL-ORD	4/20/76	0730-1429	O W
39	ORD-LAS	4/20/76	1750-2029	O W
40	LAS-ORD	4/20/76	2211-0034	O W
41	ORD-CLE	4/21/76	0308-0328	O W
42	CLE-ORD	4/21/76	1413-1433	O W
43	ORD-HNL	4/21/76	1655-0035	O W
44	HNL-SFO	4/22/76	2001-0013	O W
45	SFO-HNL	4/23/76	0411-0811	O W

TABLE I - A) FILE 0001 CONTINUED....

	FLIGHT ROUTE	DEPARTURE DATE	DATA TIME INTERVAL(GMT)	DATA
46	HNL-SFO	4/23/76	2000-2300	O W
47	HNL-DTW	4/25/76	0804-1439	O
48	CLE-ORD	4/26/76	1320-1340	O W
49	ORD-HNL	4/26/76	1604-2354	O W
50	HNL-SFO	4/27/76	2003-2348	O W
51	SFO-ORD	4/28/76	1743-2030	O W
52	ORD-SEA	4/28/76	2354-0259	O W
53	SEA-ORD	4/29/76	1518-1758	O W
54	ORD-LAX	4/29/76	2134-0050	O W
55	LAX-ITO	4/30/76	1901-0001	O W
56	ITO-LAX	5/ 1/76	0204-0529	O W
57	LAX-ORD	5/ 1/76	0805-1053	O W
58	ORD-PIT	5/ 1/76	1407-1432	O W
59	PIT-ORD	5/ 1/76	1602-1634	O W
60	ORD-LAX	5/ 1/76	1832-2112	O W
61	LAX-ITO	5/ 2/76	1905-2328	O W
62	ITO-LAX	5/ 3/76	0137-0537	O W
63	LAX-ORD	5/ 3/76	0751-1031	O W
64	ORD-PIT	5/ 3/76	1301-1326	O W
65	PIT-ORD	5/ 3/76	1543-1618	O W
66	ORD-LAX	5/ 3/76	1838-2143	O W
67	LAX-ORD	5/ 4/76	0807-1058	O W
68	ORD-PIT	5/ 4/76	1255-1325	O
69	PIT-ORD	5/ 4/76	1541-1615	O
70	ORD-LAX	5/ 4/76	1830-2140	O
71	LAX-ORD	5/ 5/76	1751-2037	O
72	ORD-LAS	5/ 6/76	1627-1912	O
73	LAS-ORD	5/ 6/76	2149-0011	O
74	ORD-HNL	5/ 7/76	1612-2347	O
75	ITO-ORD	5/ 8/76	0406-1056	O
76	ORD-LAS	5/ 8/76	1608-1843	O
77	LAS-ORD	5/ 8/76	2056-2316	O
78	ORD-CLE	5/ 9/76	0134-0149	O
79	CLE-ORD	5/ 9/76	1315-1335	O
80	ORD-HNL	5/ 9/76	1616-2335	O
81	HNL-LAX	5/10/76	1935-2354	O
82	LAX-DEN	5/11/76	0217-0337	O
83	DEN-LAX	5/11/76	1654-1814	O
84	LAX-HNL	5/11/76	2106-0050	O
85	HNL-LAS	5/12/76	0834-1353	O
86	LAS-LAX	5/12/76	1532-1542	O
87	LAX-JFK	5/12/76	1934-2349	O
88	JFK-ORD	5/13/76	1521-1631	O
89	ORD-HNL	5/13/76	1849-0219	O W
90	HNL-ORD	5/14/76	0533-1235	O

TABLE I - A) FILE 0001 CONTINUED....

	FLIGHT ROUTE	DEPARTURE DATE	DATA TIME INTERVAL (GMT)	DATA
91	ORD-LAS	5/14/76	1554-1819	O W
92	LAS-ORD	5/14/76	2105-2331	O
93	ORD-CLE	5/15/76	0138-0153	O
94	CLE-ORD	5/15/76	1327-1347	O
95	ORD-HNL	5/15/76	1646-0016	O W
96	JFK-LAX	5/16/76	1635-2049	O W
97	LAX-HNL	5/16/76	2333-0415	O W
98	SFO-HNL	5/28/76	1643-2048	O
99	HNL-LAX	5/28/76	2345-0315	O
100	LAX-HNL	5/29/76	1807-2218	O

O - OZONE
W - WATER VAPOR
F - FILTER EXPOSURE
B - BOTTLE EXPOSURE

TABLE I - GASP FLIGHTS ON TAPE VL005

B) FILE 0002 (PANAM -N655PA)

	FLIGHT ROUTE	DEPARTURE DATE	DATA TIME INTERVAL(GMT)	DATA	
1	SFO-SEA	3/25/76	1921-2031	O	
2	SEA-LHR	3/25/76	2237-0634	O	
3	LHR-SEA	3/26/76	1341-2225	O	
4	SEA-SFO	3/27/76	0120-0223	O	B
5	SFO-HNL	3/28/76	0318-0723	O	
6	HNL-GUM	3/28/76	1000-1700	O	
7	GUM-MNL	3/28/76	1908-2138	O	
8	MNL-HKG	3/28/76	2324-0024	O	
9	HKG-MNL	3/29/76	0527-0617	O	
10	MNL-GUM	3/29/76	1048-1109	O	
11	GUM-HNL	3/29/76	1316-1856	O	
12	HNL-SEA	3/30/76	0122-0532	O	
13	SEA-HNL	3/30/76	1740-2230	O	
14	HNL-SEA	3/31/76	0103-0528	O	
15	SEA-HNL	3/31/76	1745-2230	O	
16	HNL-SEA	4/ 1/76	0116-0536	O	
17	SEA-HNL	4/ 1/76	1739-2215	O	
18	HNL-SEA	4/ 2/76	0108-0538	O	
19	SEA-HNL	4/ 2/76	1739-2224	O	
20	HNL-SEA	4/ 3/76	0108-0534	O	
21	SEA-HNL	4/ 3/76	1742-2240	O	
22	HNL-LAX	4/ 4/76	1931-2326	O	
23	LAX-HNL	4/ 5/76	0301-0741	O	
24	HNL-SFO	4/ 5/76	0039-0000	O	
25	LAX-GUA	4/ 7/76	1722-2038	O	
26	GUA-CCS	4/ 8/76	0011-0233	O	
27	CCS-GIG	4/ 8/76	0459-0949	O	
28	GIG-JFK	4/10/76	0253-1122	O	
29	JFK-LHR	4/10/76	1519-2029	O	
30	LHR-AMS	4/10/76	2221-2231	O	
31	AMS-LHR	4/11/76	0033-0038	O	
32	LHR-JFK	4/11/76	1034-1724	O	
33	JFK-FCO	4/12/76	0109-0738	O	
34	FCO-JFK	4/12/76	1101-1911	O	
35	JFK-FRA	4/12/76	2234-0432	O	
36	FRA-JFK	4/13/76	1245-1950	O	
37	JFK-FRA	4/14/76	0228-0826	O	
38	FRA-JFK	4/14/76	1259-2018	O	
39	JFK-FRA	4/15/76	2220-0445	O	
40	FRA-JFK	4/16/76	1136-1824	O	
41	JFK-FRA	4/16/76	2347-0605	O	
42	FRA-MUC	4/17/76	0758-0803	O	
43	MUC-FRA	4/17/76	1038-1043	O	
44	FRA-JFK	4/17/76	1341-2044	O	
45	JFK-LHR	4/18/76	2354-0538	O	

TABLE I - B) FILE 0002 CONTINUED....

	FLIGHT ROUTE	DEPARTURE DATE	DATA TIME INTERVAL(GMT)	DATA
46	FRA-IST	4/19/76	1052-1242	O
47	IST-KHI	4/19/76	1430-1840	O
48	KHI-DEL	4/20/76	0018-0108	O
49	DEL-BKK	4/20/76	0302-0552	O
50	BKK-HKG	4/20/76	0814-1106	O
51	HKG-HND	4/21/76	0339-0626	O
52	HND-SFO	4/21/76	0848-1638	O
53	LHR-SEA	4/22/76	1426-2248	O
54	SEA-SFO	4/23/76	0114-0201	O
55	SFO-LAX	4/23/76	1626-1646	O
56	LAX-GUA	4/23/76	1913-2248	O
57	GUA-CCS	4/24/76	0111-0346	O
58	CCS-GIG	4/24/76	0553-1029	O
59	GIG-CCS	4/24/76	1512-2001	O
60	MIA-CCS	4/25/76	0250-0455	O
61	CCS-GIG	4/25/76	0700-1134	O
62	GIG-CCS	4/26/76	0517-1021	O
63	CCS-GUA	4/26/76	1235-1510	O
64	GUA-LAX	4/26/76	1749-2144	O
65	LAX-SFO	4/27/76	0014-0039	O
66	SFO-HNL	4/27/76	0429-0843	O
67	HNL-GUM	4/27/76	1058-1728	O
68	OKA-TPE	4/28/76	1643-1708	O
69	SFO-SEA	4/29/76	1819-1919	O
70	SEA-LHR	4/29/76	2139-0545	O
71	LHR-SEA	4/30/76	1228-2108	O
72	SFO-LAX	5/ 1/76	1449-1514	O
73	LAX-GUA	5/ 1/76	1727-2057	O
74	GUA-CCS	5/ 2/76	0012-0300	O
75	HNL-LAX	5/ 5/76	2058-0003	O
76	LAX-HNL	5/ 6/76	1819-2050	O
77	HNL-LAX	5/ 7/76	0015-0420	O
78	LAX-HNL	5/ 7/76	1724-2113	O
79	HNL-HND	5/ 8/76	0035-0701	O
80	HNL-SEA	5/ 8/76	2127-0209	O
81	HNL-HND	5/10/76	0008-0701	O
82	HNL-HND	5/12/76	0145-0858	O
83	HND-HNL	5/12/76	1240-1825	O
84	HNL-SFO	5/12/76	2328-0318	O
85	SFO-LAX	5/13/76	1454-1518	O
86	LAX-GUA	5/13/76	1731-2053	O

O - OZONE
W - WATER VAPOR
F - FILTER EXPOSURE
B - BOTTLE EXPOSURE

TABLE I - GASP FLIGHTS ON TAPE VL005

C) FILE 0003 (PANAM -N533PA)

	FLIGHT ROUTE	DEPARTURE DATE	DATA TIME INTERVAL(GMT)	DATA	
1	JFK-SFO	4/13/76	1437-1913	O	
2	SFO-JFK	4/14/76	1819-2232	O	
3	JFK-SFO	4/15/76	1436-1939	O	
4	SFO-JFK	4/16/76	1811-2231	O	
5	JFK-SFO	4/17/76	1422-1859	O	
6	SFO-JFK	4/18/76	1810-2220	O	
7	JFK-SFO	4/19/76	1417-1902	O	
8	SFO-JFK	4/20/76	1814-2223	O	
9	JFK-LHR	4/21/76	1517-2112	O	
10	LHR-BRU	4/21/76	2228-2238	O	
11	BRU-LHR	4/22/76	0809-0819	O	
12	LHR-JFK	4/22/76	1038-1632	O	
13	JFK-FRA	4/23/76	0138-0821	O	
14	FRA-JFK	4/23/76	1249-1930	O	
15	JFK-FRA	4/23/76	2347-0632	O	
16	FRA-JFK	4/24/76	1300-1933	O	
17	JFK-HND	4/26/76	1644-0527	O	
18	HND-LAX	4/27/76	1011-1846	O	
19	LAX-HND	4/28/76	1950-0600	O	
20	HND-LAX	4/29/76	0947-1832	O	
21	LAX-JFK	4/29/76	2056-0050	O	
22	JFK-IND	4/30/76	1614-1719	O	
23	IND-JFK	4/30/76	2317-0010	O	
24	JFK-DEL	5/ 1/76	2154-1049	O	
25	LAX-HND	6/ 4/76	1956-0111	O	
26	SFO-LAX	6/ 8/76	1742-1806	O	
27	LAX-HND	6/10/76	2011-0638	O	B
28	HND-JFK	6/13/76	1005-2136	O	

O - OZONE
W - WATER VAPOR
F - FILTER EXPOSURE
B - BOTTLE EXPOSURE

TABLE II - NMC TROPOPAUSE PRESSURE DATA
ON GASP TAPE VL0005

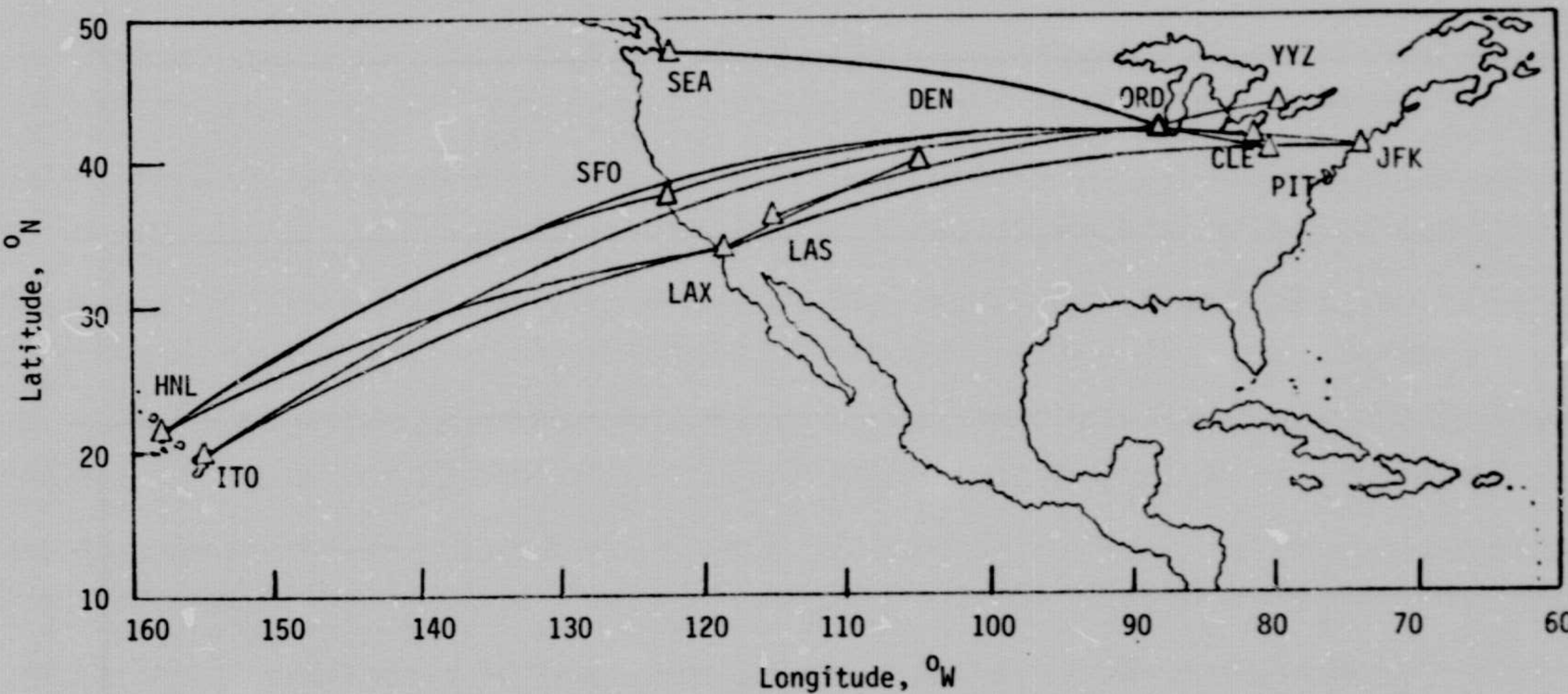
	From	Through
1	3/25/76, 1200 GMT	5/17/76, 1200 GMT
2	5/28/76, 1200 GMT	5/30/76, 0000 GMT
3	6/04/76, 1200 GMT	6/05/76, 1200 GMT
4	6/08/76, 1200 GMT	6/14/76, 0000 GMT

Table III - Zonal Averaged NMC Tropopause Pressure Data, January 1975 - October 1976

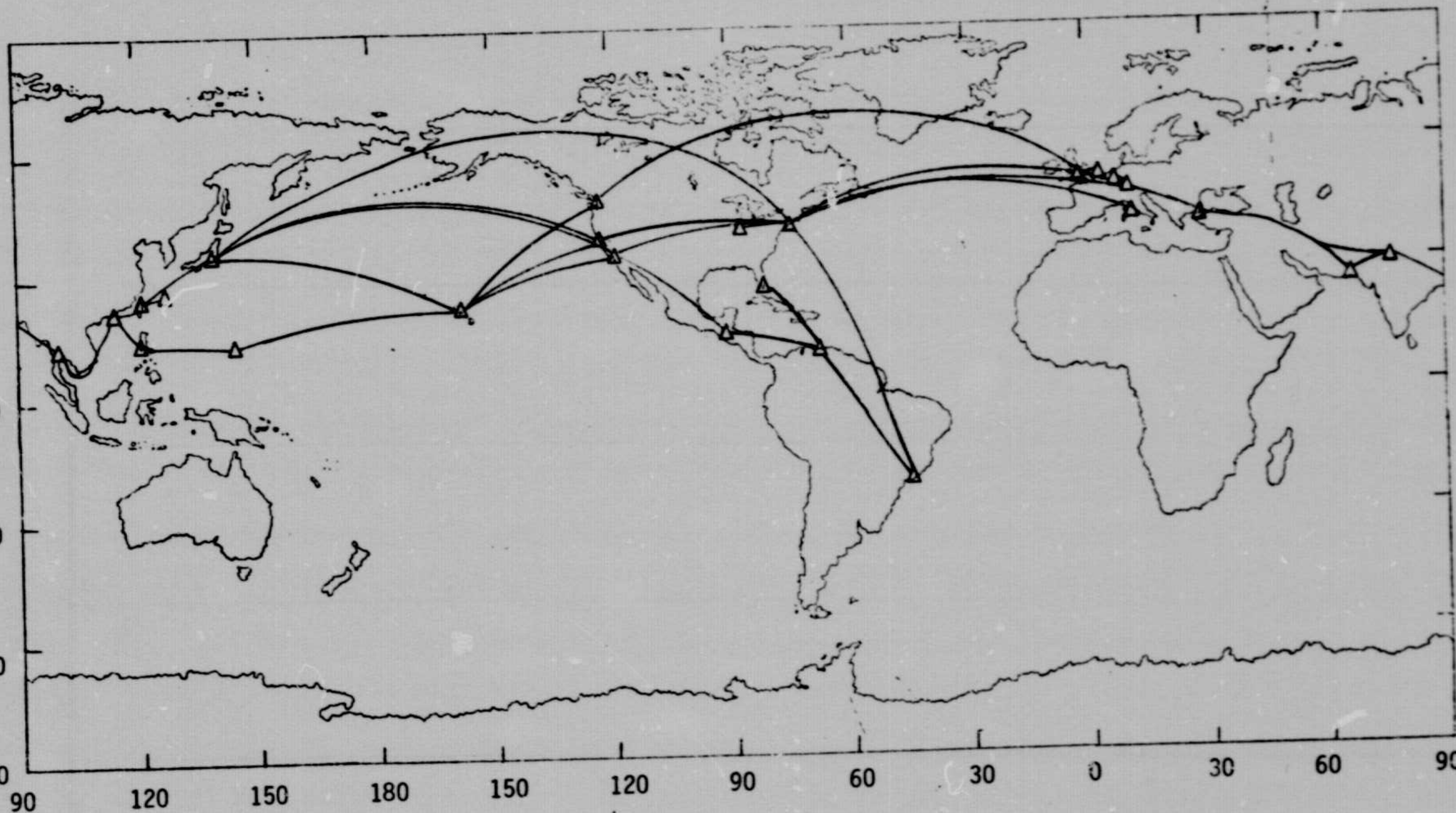
		LATITUDE (Degrees North)													
	MONTH	20	25	30	35	40	45	50	55	60	65	70	75	80	85
1975	J	131.5	138.3	165.5	210.6	234.6	243.9	253.5	262.1	267.4	268.1	264.6	260.8	256.9	251.8
	F	134.3	153.5	189.5	223.6	241.3	254.1	262.6	265.1	264.4	262.0	261.8	264.8	265.9	264.3
	M	132.6	149.0	183.2	212.8	228.7	242.9	255.3	262.9	268.1	274.3	281.5	286.7	287.5	285.1
	A	134.0	145.2	169.3	195.4	212.9	226.0	239.3	251.3	262.7	275.0	287.9	299.4	306.5	308.7
	M	130.2	135.1	154.9	184.9	207.1	221.7	234.9	247.0	258.6	269.3	278.0	286.6	297.2	304.9
	J	130.2	130.7	135.4	152.3	180.3	205.7	220.8	232.2	244.9	256.7	267.4	277.1	281.9	280.8
	J	130.3	130.5	130.6	133.9	150.7	182.7	213.0	229.1	235.9	242.8	252.8	261.4	265.7	267.2
	A	130.4	130.8	131.1	133.9	148.7	179.8	211.1	227.9	235.4	240.5	247.0	256.0	265.2	270.8
	S	130.3	131.[illegible]	132.1	137.7	158.2	191.6	218.4	232.7	242.2	251.5	262.5	272.4	276.6	275.1
	O	132.0	132.8	136.4	151.8	182.3	215.4	237.5	247.0	251.4	257.7	267.7	277.9	286.3	292.1
	N	131.1	134.4	145.1	172.2	201.9	223.0	239.0	252.2	263.0	270.3	273.6	275.7	279.9	285.5
	D	155.3	165.3	190.0	226.0	251.5	261.9	268.0	273.3	278.1	282.0	284.8	286.3	287.1	288.5
1976	J	192.0	209.3	237.0	267.4	286.2	292.4	295.8	298.9	298.6	294.2	288.4	285.3	283.1	277.6
	F	192.6	211.0	242.6	266.5	280.2	293.9	305.1	307.8	302.2	294.2	287.6	282.5	280.5	280.3
	M	187.6	204.1	232.8	255.5	274.2	292.8	306.7	312.0	310.7	302.9	292.2	284.2	280.5	278.7
	A	181.7	191.9	214.3	236.4	255.5	273.6	287.9	298.7	308.8	319.2	328.4	334.8	334.4	329.3
	M	179.4	186.7	202.8	221.1	239.6	258.8	277.5	294.9	308.0	315.7	322.8	332.8	341.5	344.9
	J	176.2	184.8	194.8	207.3	225.8	246.0	262.6	277.3	289.2	300.2	313.5	325.3	330.0	327.5
	J	160.2	172.7	183.6	194.7	212.3	234.8	255.8	266.7	273.3	283.4	296.6	308.1	317.9	326.6
	A	150.3	160.5	172.3	185.7	206.0	232.1	252.7	264.6	272.5	279.7	291.0	307.9	324.9	334.2
	S	165.2	173.4	184.2	196.4	215.9	237.2	255.2	269.2	278.8	286.5	294.4	303.0	313.4	323.9
	O	172.3	175.1	185.5	204.1	221.6	241.2	265.9	287.5	297.8	301.6	303.8	306.3	312.3	322.1

TABLE IV - SAMPLE BOTTLE DATA ON TAPES VL0004 & VL0005

GASP Identification					
Bottle no.	10-1	10-2	10-3	10-4	4-2
Analysis no.	20	41	33	39	108
Tape	VL0004	VL0004	VL0004	VL0005	VL0005
File, flight	2,45	2,55	2,63	2,4	3,27
Sample Data					
Data	3/18/76	3/21/76	3/24/76	3/27/76	6/10/76
Latitude, deg	41N	44N	26N	44N	36N
Longitude, deg	78W	65W	82E	123W	120W
Altitude, km	10.7	10.1	11.3	11.3	9.8
Region	troposphere	troposphere	troposphere	stratosphere	stratosphere
Pressure, kPa	32	36	29	30	41
Constituent Data					
F-11, pptv	102	105	106	93	111



a) File 1 - United Airlines (N4711U)
Figure 1. GASP Flight Routes for Tape VL0005



b) File 2 - Pan American World Airways (N655PA)
File 3 - Pan American World Airways (N533PA)

Figure 1. GASP Flight Routes for Tape VL0005

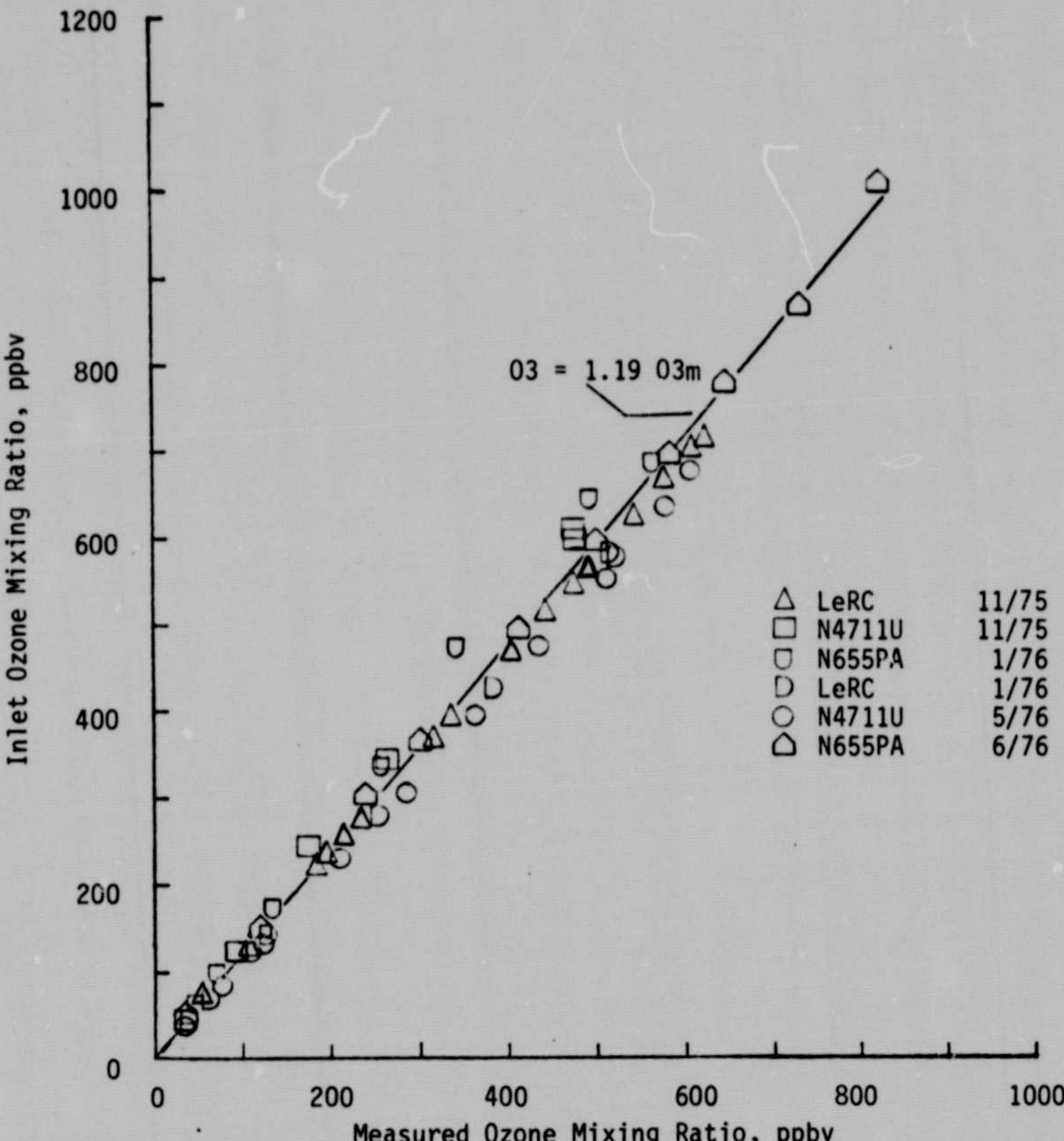


Figure 2. GASP System Ozone Destruction Test Results

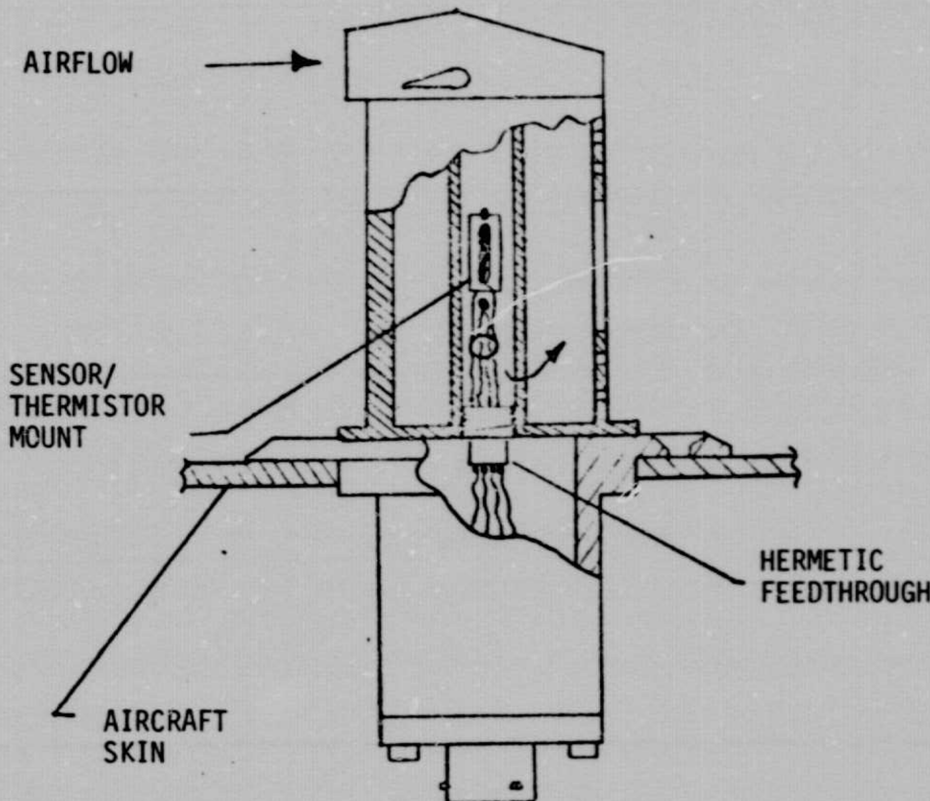


Figure 3 - GASP Water Vapor Sampling Probe/Sensor Configuration. Rosemount Probe Model H102KD. Panametrics Sensor Model MIT-N

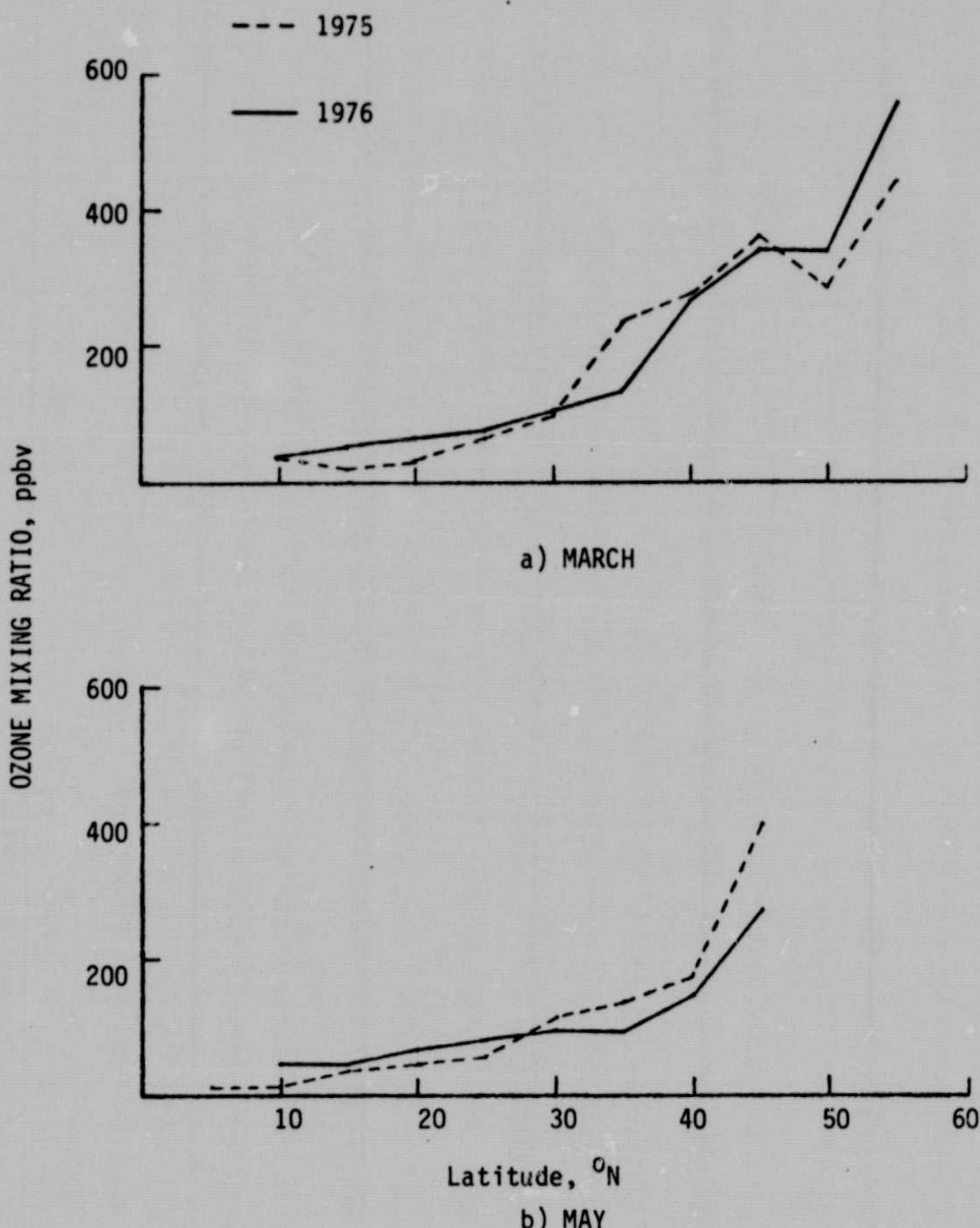


Figure 4. Latitudinal variation of ozone mixing ratio at 11 ± .5 km for March and May, 1975 and 1976.

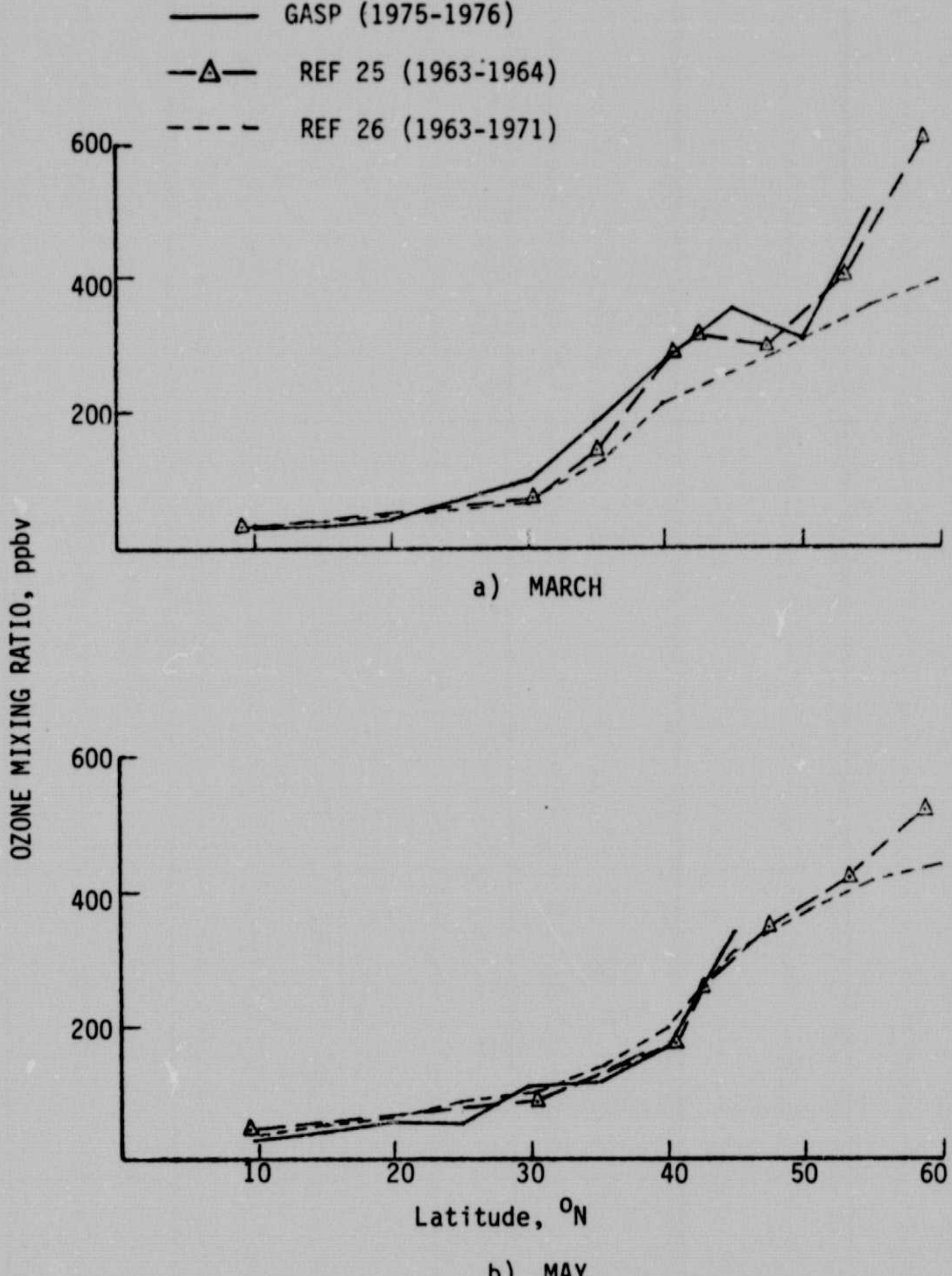


Figure 5. Variation of ozone mixing ratio with latitude for March and May. GASP Data for altitudes 10.5 - 11.5 km. Ref. 25 and 26 Data interpolated to 11 km.

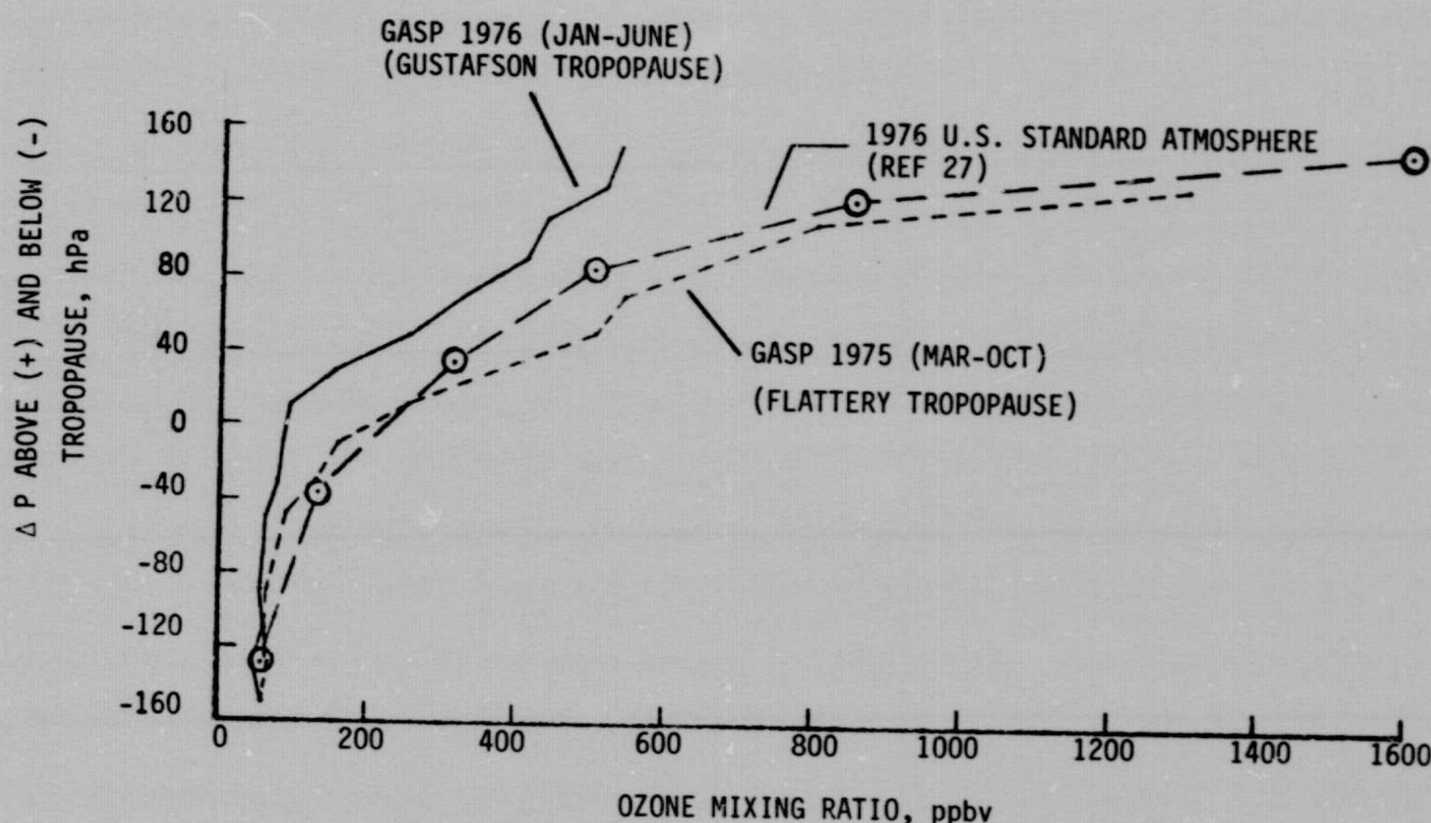


FIGURE 6. VERTICAL OZONE PROFILE WITH RESPECT TO NMC TROPOPAUSE FOR GASP 1975 AND 1976 DATA

APPENDIX A - Specifications for GASP Archive Tapes (VLXXXX)

GENERAL

1. Tapes are written in EBCDIC format using nine track tapes.
2. Tape density is 800 BPI.
3. Physical records (blocks) are 4096 bytes.
4. The tapes are unlabeled, and contain one or more GASP data files followed by a tropopause pressure data file.

GASP DATA FILE

1. Each GASP data file contains data from a single GASP aircraft. Within each file, data are grouped and identified by flights (takeoff to landing) in chronological order.
2. The GASP data for each flight begins with a logical FLHT record (flight identification data), which is followed by logical DATA records (one for each data recording made during the flight). Both FLHT and DATA records contain 512 bytes, hence there are 8 logical records per physical record (block).
3. A FLHT record will always be the first logical record in a block. However, every block need not begin with a FLHT record (i.e., if there are more than seven DATA records in a flight). If the FLHT record plus the available DATA records for a flight do not fill an integer number of blocks, the unused logical records in the final block are padded with zeros creating PADD records. The diagram below shows how several short flights would be blocked.

```
Block                 1                     2                     3
           ---------------------  ---------------------  ---------------------
             F D D D D D P P        F D D D D D D D        D D P P P P P P
           ---------------------  ---------------------  ---------------------
Logical
Record       1 2 3 4 5 6 7 8        1 2 3 4 5 6 7 8        1 2 3 4 5 6 7 8
```

Block	4	5	6
	F D D D D D D D	D D D D D D D D	F D D D D D D P
Logical Record	1 2 3 4 5 6 7 8	1 2 3 4 5 6 7 8	1 2 3 4 5 6 7 8

where F is a FLHT record
D is a DATA record
P is a PADD record

4. The first four bytes in each logical record identify the record type as FLHT, DATA, or PADD. Detailed specification of the parameters and formats for FLHT and DATA records are given in Table A-I and A-II respectively.

   a) In each FLHT record, the number of DATA records to follow is given by NDATA (Bytes 78-81), and the number of blocks in the flight is given by NBLOCK (Bytes 82-84).
   b) For the last DATA record of each flight, LBFLG (Byte 5) = "L"; for the last DATA record in each file, LBFLG = "G" if the following file is a GASP data file, and LBFLG = "T" if the following file is the tropopause pressure file; for all other DATA records, LBFLG = " ".

   Note: DATA records with LBFLG ≠ " " will be followed by PADD records if the physical record (block) is not complete.

TROPOPAUSE PRESSURE DATA FILE

1. Following the GASP data, in a separate file, tropopause pressure data for the dates of the GASP flights are included. Data are currently available from the National Meteorological Center (NMC) twice daily for 4225 locations in the Northern Hemisphere. Coordinates for these data are the NMC 65X65 square matrix grid, transformed from a polar stereographic map of the Northern Hemisphere.

2. Each 65X65 tropopause pressure array is written as seven TRPR records. Each TRPR record is a physical record (block), and is the same length as the GASP physical records (4096 bytes). All TRPR records contain identification information. Specifications and formats for the TRPR records are given in Table A-III.

Table A-I Format for FLHT Records

Bytes	Fortran Name	Fortran Format	Parameter Description, Units, and Comments
1-4	RECID	A4	RECID = "FLHT"
5-10	TAPID	A6	Original GASP tape number, GPXXX
11-25	ACID	A15	Aircraft ID; Airline and tail number
26-28	APTLV	A3	Airport of departure (3 letter code)
29-34	DATLV	I6	Date first DATA record this flight; Mo=29-30, Da=31-32, Yr=33-34
35-38	TIMLV	A4	Time (GMT) first DATA record this flight; Hr=35-36, Min=37-38
39-43	LATLV	F5.2	Latitude (deg) of APTLV
44	LALVT	A1	Hemisphere of LATLV; "N" or "S"
45-50	LONLV	F6.2	Longitude (deg) of APTLV
51	LOLVT	A1	Hemisphere of LONLV; "E" or "W"
52-54	APTAR	A3	Airport of arrival (3 letter code)
55-60	DATAR	I6	Date last DATA record this flight; Mo=55-56, Da=57-58, Yr=59-60
61-64	TIMAR	A4	Time (GMT) last DATA record this flight; Hr=61-62, Min=63-64
65-69	LATAR	F5.2	Latitude (deg) of APTAR
70	LAART	A1	Hemisphere of LATAR, "N" or "S"
71-76	LONAR	F6.2	Longitude (deg) of APTAR
77	LOART	A1	Hemisphere of LONAR, "E" or "W"
78-81	NDATA	I4	Number of DATA records for this flight
82-84	NBLOCK	I3	Total number of blocks for this flight
85-87	O3ID	A3	Ozone instrument ID number*
88-90	COID	A3	Carbon monoxide instrument ID number*
91-93	PCSID	A3	Particle counter sensor ID number*
94-96	PCEID	A3	Particle counter electronics ID number*
97-99	H2OID	A3	Water vapor sensor ID number*
100-102	HYGID	A3	Hygrometer ID number*
103-105		A3	Spare ID
106-108		A3	Spare ID
109-111		A3	Spare ID
112-114		A3	Spare ID

Table A-I Continued

Bytes	Fortran Name	Fortran Format	Parameter Description, Units, and Comments
115-117		A3	Spare ID
118-122	D1	F5.3	Smallest particle radius (micrometers) for PC range 1
123-127	D2	F5.3	Smallest particle radius (micrometers) for PC range 2
128-132	D3	F5.3	Smallest particle radius (micrometers) for PC range 3
133-137	D4	F5.3	Smallest particle radius (micrometers) for PC range 4
138-142	D5	F5.3	Smallest particle radius (micrometers) for PC range 5
143	LIMCHK	A1	LIMCHK="T" if ACC limit exceeded (NE .GT. 0) on any DATA record this flight; otherwise LIMCHK="F"
144	FILEX	A1	FILEX="T" if filter exposed this flight; otherwise FILEX="F"
145	FDATA	A1	FDATA="T" if filter data on tape; otherwise FDATA="F"
146-149	FPAKN	I4	Filter pack number
150-151	FILTN	I2	Filter number
152-161	FTYPE	A10	Filter type
162-167	FDATON	I6	Filter exposure start date; Mo=162-163, Da=164-165, Yr=166-167
168-171	FTIMON	A4	Filter exposure start time; (GMT); Hr=168-169, Min 170-171
172-176	FLATON	F5.2	Filter exposure start latitude (deg)
177	FLAONT	A1	Filter exposure start latitude tag; "N" or "S"
178-183	FLONON	F6.2	Filter exposure start longitude (deg)
184	FLOONT	A1	Filter exposure start longitude tag; "E" or "W"
185-190	FHTMON	F6.0	Filter exposure start altitude (meters)
191-196	FDATOF	I6	Filter exposure stop date; Mo=191-192, Da=193-194, Yr=195-196
197-200	FTIMOF	A4	Filter exposure stop time (GMT); Hr=197-198, Min=199-200
201-205	FLATOF	F5.2	Filter exposure stop latitude (deg)
206	FLAOFT	A1	Filter exposure stop latitude tag; "N" or "S"
207-212	FLONOF	F6.2	Filter exposure stop longitude (deg)
213	FLOOFT	A1	Filter exposure stop longitude tag; "E" or "W"
214-219	FHTMOF	F6.0	Filter exposure stop altitude (meters)
220-229	FCOMP1	A10	Filter constituent 1 (name)
230-239	FCOMP2	A10	Filter constituent 2 "

Table A-I Continued

Bytes	Portran Name	Portran Format	Parameter Description, Units, and Comments
240-249	FCOMP3	A10	Filter constituent 3 "
250-259	FCOMP4	A10	Filter constituent 4 "
260-269	FCOMP5	A10	Filter constituent 5 "
270-279	FDC1	F10.3	Data for constituent 1 (micrograms/M**3)
280-289	FDC2	F10.3	Data for constituent 2 (micrograms/M**3)
290-299	FDC3	F10.3	Data for constituent 3 (micrograms/M**3)
300-309	FDC4	F10.3	Data for constituent 4 (micrograms/M**3)
310-319	FDC5	F10.3	Data for constituent 5 (micrograms/M**3)
320	SBUEX	A1	SBUEX="T" if bottle exposed this flight, otherwise SBUEX="F"
321	SDATA	A1	SDATA="T" if bottle data on tape; otherwise SDATA="F"
322-324	SBID	I3	Sample bottle unit number
325-326	STBN	I2	Bottle number
327-332	SDATON	I6	Bottle exposure start date; Mo=327-328, DA=329-330, Yr=331-332
333-336	STIMON	I4	Bottle exposure start time (GMT); Hr=333-334, Min=335-336
337-341	SLATON	F5.2	Bottle exposure start latitude (deg)
342	SLAONT	A1	Bottle exposure start latitude tag, "N" or "S"
343-348	SLONON	F6.2	Bottle exposure start longitude (deg)
349	SLOONT	A1	Bottle exposure start longitude tag "E" or "W"
350-355	SHTMON	F6.0	Bottle exposure start altitude (meters)
356-361	SDATOF	I6	Bottle exposure stop date; Mo=356-357, DA=358-359, Yr=360-361
362-365	STIMOF	I4	Bottle exposure stop time (GMT); Hr=362-363, Min=364-365
366-370	SLATOF	F5.2	Bottle exposure stop latitude (deg)
371	SLAOFT	A1	Bottle exposure stop latitude tag; "N" or "S"
372-377	SLONOF	F6.2	Bottle exposure stop longitude (deg)
378	SLOOFT	A1	Bottle exposure stop longitude tag; "E" or "W"
379-384	SHTMOF	F6.0	Bottle exposure stop altitude (meters)
385-394	SCOMP1	A10	Bottle constituent 1 (name)
395-404	SCOMP2	A10	Bottle constituent 2 "
405-414	SCOMP3	A10	Bottle constituent 3 "

Table A-I Completed

Bytes	Fortran Name	Fortran Format	Parameter Description, Units, and Comments
415-424	SCOMP4	A10	Bottle constituent 4 "
425-434	SCOMP5	A10	Bottle constituent 5 "
435-444	SDC1	F10.1	Data for constituent 1 (PPTV)
445-454	SDC2	F10.1	Data for constituent 2 "
455-464	SDC3	F10.1	Data for constituent 3 "
465-474	SDC4	F10.1	Data for constituent 4 "
475-484	SDC5	F10.1	Data for constituent 5 "
485-489	a	F5.3	O3 destruction constant (see eq. 1)
490-494	b	F5.3	O3 destruction constant (see eq. 1)
495-499	c	F5.1	O3 destruction constant (see eq. 1)
500-507	d	E8.2	O3 destruction constant (see eq. 1)
508-512		5A1	Spares

*if ID="M", no data for this instrument this flight

Table A-II Format for DATA Records

Bytes	Fortran Name	Fortran Format	Parameter Description, Units, and Comments
1-4	RECID	A4	RECID= "DATA"
5	LBFLG	A1	LBFLG="L" if this is the last data record this flight; LBFLG="G" If this is the last GASP data record in the file and the following file is a GASP data file; LBFLG="T" If this is the last GASP data record in the file and the following file is a tropopause pressure file; otherwise LBFLG=" "
6-9	RECORD	I4	Record number on TAPID
10	FRAME	I1	Frame number on TAPID
11-12	MODE	I2	Program mode from DMCU MODE = 4 identifies a normal recording MODE = 10 identifies a continuous recording
13	TYPE	A1	Record type from DMCU
14	CYCLE	A1	Cal set up from DMCU
15-20	DATE	I6	Mo=15-16, Da=17-18, Yr=19-20
21-24	TIME	A4	(GMT), Hr=21-22, Min=23-24
25-30	ALTFAV	F6.0	Altitude (ft)
31-36	ALTMAV	F6.0	Altitude (meters)
37-43	PAMB	F7.2	Ambient static pressure in hectopascals (mb) - calc from ALTFAV
44	ALTAG	A1	ALTAG="C", "D", or "G" indicates climb, descent, or ground
45-49	LAT	F5.2	Latitude (deg)
50	LATAG	A1	Latitude hemisphere, "N" or "S"
51-56	LONG	F6.2	Longitude (deg)
57	LONGTAG	A1	Longitude hemisphere, "E" or "W"
58-62	XI	F5.2	Aircraft position in NMC grid coordinates
63-67	YJ	F5.2	Aircraft position in NMC grid coordinates
68-71	HEADG	F4.0	Aircraft heading (deg)

Table A-II Continued

Bytes	Fortran Name	Fortran Format	Parameter Description, Units, and Comments
72	HEADGT	A1	Tag for HEADG*
73-76	TASK	F4.0	True airspeed (knots)
77-81	XMATAS	F5.3	Flight mach number
82	TATAG	A1	Tag for TASK and XMATAS*
83-86	WS	F4.0	Wind speed (knots)
87-90	WSM	F4.0	Wind speed (meters/sec)
91	WSTAG	A1	Tag for WS and WSM*
92-95	WDEG	F4.0	Wind direction (deg)
96	WDEGTG	A1	Tag for WDEG*
97-100	SAT	F4.0	Static (ambient) air temperature (deg C)
101	SATAG	A1	Tag for SAT*
102-229	ACC(I)	32F4.2	Aircraft acceleration (gs); 32 values each record at 8/sec
230-233	ACCMAX	F4.2	Max of ACC(I)
234-237	ACCMIN	F4.2	Min of ACC(I)
238-239	NE	I2	Number of times ACC(I) > 1.2 or ACC(I) < 0.8
240	ACCTAG	A1	Tag for ACC(I), ACCMAX, ACCMIN, NE*
241-245	ZEN	F5.1	Solar elevation angle (deg); 0 deg = horizontal
246	SUNTAG	A1	SUNTAG="N" if sun below horizon
247-252	O3	F6.0	Ozone data (PPBV)
253	O3TAG	A1	Tag for O3*
254-259	O3A	F6.0	Ozone data (PPBV); ave for 128 sec preceding recording
260	O3ATAG	A1	Tag for O3A*
261-266	O3S	F6.0	Ozone std deviation (PPBV); for 128 sec preceding recording
267	O3STAG	A1	Tag for O3S*
268-273	DFPTA	F6.1	Dew/frost point temperature (deg C)
274-279	WVMRA	F6.1	Water vapor mixing ratio (PPMW)
280	DFTAGA	A1	Tag for DFPTA and WVMRA; if DFPTA=SAT, DFTAGA="S"*
281-286	COAVG	F6.3	Carbon monoxide data (PPMV)
287	COTAGA	A1	Tag for COAVG*
288-293	COA	F6.3	Carbon monoxide data (PPMV); ave for 128 sec preceding recording
294	COATAG	A1	Tag for COA*

Table A-II Completed

Bytes	Fortran Name	Fortran Format	Parameter Description, Units, and Comments
295-300	COSD	F6.3	Carbon monoxide std deviation (PPMV); for 128 sec preceding recording
301	COSTAG	A1	Tag for COSD*
302-311	PD1	1PE10.3	Particle density for particles > D1 (particles/M**3)
312	PDTAG1	A1	Tag for PD1*
313-322	PD2	1PE10.3	Particle density for particles > D2 (particles/M**3)
323	PDTAG2	A1	Tag for PD2*
324-333	PD3	1PE10.3	Particle density for particles > D3 (particles/M**3)
334	PDTAG3	A1	Tag for PD3*
335-344	PD4	1PE10.3	Particle density for particles > D4 (particles/M**3)
345	PDTAG4	A1	Tag for PD4*
346-355	PD5	1PE10.3	Particle density for particles > D5 (particles/M**3)
356	PDTAG5	A1	Tag for PD5*
357-361	CLSEC	F5.0	Time in clouds (sec) during 255 sec preceding recording
362-365	CLAYR	F4.0	Number of cycles in and out of clouds (layers) during 255 sec preceding recording
366	CLTAG	A1	Tag for CLSEC and CLAYR; if CLSEC > 0, CLTAG="C"*
367-373	TRPRMB	F7.2	Tropopause pressure in hectopascals (mb)
374	TPTAG	A1	If TPTAG = " ", TRPRMB from 12 hour interpolation If TPTAG = "L", TRPRMB from 24 hour interpolation If TPTAG = "E", TRPRMB from nearest NMC reporting period If TPTAG = "M", NMC data is not available See the report text for a complete description of TPTAG criteria
375-381	DELP	F7.2	DELP = TRPRMB - PAMB, in hectopascals (mb)
382-387	TRPRHM	F6.0	Tropopause height in meters (from TRPRMB assuming std. atm.)
388-394	DELHGT	F7.0	DELHGT = ALTMAV - TRPRHM, in meters
395	GMTTAG	A1	Tag for TIME*
396-512		117A1	SPARES

*If TAG="M", corresponding data field will be zero; the "M" tag is used whenever data are not available or an instrument is in a calibration mode.

Table A-III Format for TRPR Records

Bytes	Fortran Name	Fortran Format	Parameter Description, Units, and Comments
1-4	RECID	A4	RECID = "TRPR"
5	HEMIS	A1	HEMIS= "N" for Northern Hemisphere
6-11	DATE	3I2	Date of Observation; Mo=6-7; Da=8-9; Yr=10-11
12-15	TIME	2A2	GMT of Observation; Hr=12-13; Min=13-14
16	NBLOCK	I1	NBLOCK = Block Counter this data array
17-18	ISTART	I2	ISTART = 1+(NBLOCK-1)*10
19-20	ISTOP	I2	ISTOP = NBLOCK*10 for NBLOCK = 1-6;ISTOP = 65 for NBLOCK=7
21-22	JSTART	I2	JSTART = 1
23-24	JSTOP	I2	JSTOP = 65
25-30	SCALE	E6.1	Scale factor for TROP(I,J)
31-43	A	E13.6	Base for TROP(I,J)
44-100		57I1	Spares
101-4000	ELE(I,J)	650I6	Tropopause Pressures in hectopascals (mb), TROP(I,J)=ELE(I,J)*SCALE+A where: ((ELE(I,J),I = ISTART,ISTOP),J = JSTART,JSTOP) Note that in the seventh block of each array only bytes 101-2050 are needed.
4001-4096		96I1	Spares

APPENDIX B - LATITUDE AND LONGITUDE FROM NMC COORDINATES

The tropopause pressure data included in GASP TRPR records are given at each of the 4225 points on the NMC 65 X 65 grid, a square matrix transformed from a polar stereographic map of the Northern Hemisphere. In the NMC coordinates the North Pole is the point (33,33), with the 10 deg E - 170 deg W meridian given by the line YJ = 33, and the 100 deg E - 80 deg W meridian given by the line XI = 33. The transformation from this coordinate system to latitude (deg N or S) and longitude (deg E or W) is as follows:

$$\text{Let } R^2 = ((XI-33)^2 + (YJ-33)^2)/RHO^2 \qquad (A1)$$

where RHO = 31.2043

The Latitude (deg) is given by

$$THETA = (180/PI)\ \arcsin((1-R^2)/(1+R^2)) \qquad (A2)$$

If THETA > 0, LAT = THETA and LATAG = "N"

If THETA < 0, LAT = -THETA and LATAG = "S"

The Longitude (deg) is given by

$$PHI = -(10 + (180/PI)\ \arctan((YJ-33)/(XI-33)) \qquad (A3)$$

If -190 < PHI < -180 , Long = PHI + 360 and LONGTAG = "W"

If -180 < PHI < 0 , LONG = -PHI and LONGTAG = "E"

If 0 < PHI < 170 , LONG = PHI and LONGTAG = "W"